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Sound Perception of Different Materials for the Footpaths of Urban Parks

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Abstract

Over the years the environmental potential of urban parks has attracted increasingly attention. In order to preserve their positive influence for communities, the sonic environment perception (soundscape) must be considered too. Urban parks' sonic environment is influenced by attenders moving around; indeed, walking sounds have very high occurrence in such contexts. However, studies investigating both walking sounds and soundscape are limited. This study investigates the influence of different footpath materials on the sonic perception. A laboratory listening experiment was carried out with four walked-on materials: grass, wood, stone and gravel. Preliminary results show a significant material effect on soundscape perception.

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Keywords: soundscape; urban parks; sound perception; noise annoyance

1. Introduction

The Directive 2002/49/EC of the European Parliament and of the Council relating to the Assessment and Management of Environment Noise [1] urges the Member States of the European Union to protect 'quiet areas'. Since the definition of such areas was rather vague, the European Environment Agency (EEA) published a 'Good practice guide on quiet areas' in 2014 [2], where four complementary methods for identifying quiet areas are suggested: (1) noise mapping, (2) sound level measurements, (3) the soundscape approach, and (4) expert

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assessments. Soundscape itself has been recently defined in the ISO 12913 as the “acoustic environment as perceived or experienced and/or understood by a person or people, in context” [3].

Within the city realm, quiet areas often coincide with urban parks. Therefore, the individual perception of the acoustic environment (i.e. the soundscape) in such context has received increasingly attention from researchers [4, 5, 6, 7, 8, 9, 10, 11, 12]. One of the main aspects to consider in the soundscape approach is how the sound sources – either natural, anthropic or mechanical sources– interact with the environment and how they are eventually perceived by the individuals.

Walking sound –that is, the sound of the footsteps of an individual– is a typical sound source in urban parks; although, it has been considered in very few researches so far, and mainly for indoor environments [13]. This study aimed to investigate the effect of walking sounds on the soundscape of urban parks for people with both a holistic or attentive listening style. To this purpose, a laboratory experiment involving fifty participants was carried out with four plausible walked-on materials: grass, wood, stone and gravel. Results were afterwards compared with data collected from an online survey presented to different users’ groups.

2. Methods and materials

2.1. Participants

Two groups of participants were selected to take part in the experiment, separately at the University of Sheffield (UK) and at the Politecnico di Torino (Italy). The sample in Sheffield consisted of twenty-five undergraduates and postgraduates, 21 to 41 years old (14 women and 11 men, M_{age} = 27.0 years, SD = 4.49). Similarly, the sample in Torino consisted of twenty-nine undergraduates and postgraduates, 22 to 45 years old (16 women and 13 men, M_{age} = 28.3 years, SD = 8.36).

The rationale for having two groups of participants in different countries with significant ethnic variation was to investigate possible socio-cultural effects in the responses to the stimuli of the experiment. Indeed, previous findings in literature confirm that generally differences exist between different cultural groups regarding the noticeability of noise source and the sound preference [14].

2.2. Stimulus material

Four walking sounds were recorded in the anechoic chamber of the University of Sheffield (Fig.1). Those corresponded to four selected walked-on materials that are likely to be used for the footpaths of urban parks: grass, wood, stone and gravel. The walking sounds were recorded by means of two in-ear 1/8” binaural microphones (left and right) and a portable recorder (Edirol R-44). For each material, the experimenter wore the binaural microphones and walked back and forth at a speed of 2 steps/s for 15 s [13].

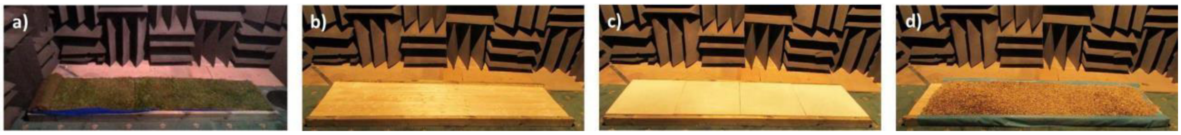

Fig. 1. The four materials used to record the walking sounds: (a) grass; (b) wood; (c) stone; (d) gravel.

A generally quiet background sound ($L_{Aeq\text{-}15\ secs}$ = 55.0 dB) was recorded at a fixed position in Weston Park (Sheffield, UK) by means of a dummy head (Neumann KU100) connected to a portable recorder (Edirol R-44). Similarly, a noisier background sound ($L_{Aeq\text{-}15\ secs}$ = 62.8 dB) was recorded in Valley Gardens (Brighton, UK). Weston Park was selected to represent a sonic environment with a balanced composition of natural, anthropic and non-intrusive mechanical sounds. On the other hand, Valley Gardens site was selected for it is more exposed to traffic noise. Although, in order to control for possible noise level effects, the L_{Aeq} of Valley Gardens was adjusted by means of an audio-editing software as per the Weston Park site. Table 1 shows the sound-pressure level (SPL), loudness (L), roughness (R), sharpness (S), fluctuation strength (Fls) and tonality (Ton) values for the four materials and the background noises in Weston Park and Valley Gardens.

Afterwards, the four materials' recordings were calibrated and mixed accordingly with the two background noises, to obtain eight different auditory stimuli (combination of walking sounds and background).

Table 1. Acoustic metrics of the walking sounds on the four selected materials and the two selected backgrounds.

	SPL - dB(A)	L - soneGF	R - asper	S - acum	Fls - vacil
Grass	28.5	0.81	0.047	2.680	0.014
Wood	48.6	3.04	1.180	1.720	0.177
Stone	40.1	2.23	0.628	1.880	0.051
Gravel	66.1	15.05	3.580	2.695	0.354
Background – Weston Park	55.0	9.06	1.315	1.930	0.013
Background – Valley Gardens (*edited*)	55.0	10.60	1.620	1.890	0.012

2.3. Experimental design and procedure

The experimental design relied on the manipulation of three multi-levelled factors: Walking sound (WS), Background (BN) and Task (TK). The WS factor had four levels: Grass, Wood, Stone and Gravel; the BN factor had two levels: Weston Park and Valley Gardens; the TK factor had two levels: No Task and Cognitive Task References. The design consisted of twelve experimental conditions derived from the combination of the factors' levels as per Table 2. Not all possible combinations were selected to be experimental conditions; the rationale for such an experimental design was to start from a 'reference' condition (i.e. Walking sounds/Weston Park/No Task) and manipulate in turn the two remaining factors.

Table 2. Definition of the twelve experimental conditions.

	Walking sound				Background		Task	
Experimental condition	Grass	Wood	Stone	Gravel	Weston Park	Valley Gardens	No Task	Cognitive Task
1	x				x		x	
2		x			x		x	
3			x		x		x	
4				x	x		x	
5	x					x	x	
6		x				x	x	
7			x			x	x	
8				x		x	x	
9	x				x			x
10		x			x			x
11			x		x			x
12				x	x			x

Both in Torino and Sheffield participants took part individually in an anechoic chamber, with background noise lower than 25 dB(A), through an automated procedure conducted via a laptop and calibrated headphones (Sennheiser HD 600). The twelve experimental conditions were submitted to participants in a randomized sequence to control for possible order effects. The cognitive task consisted of sums of two digits with the same level of difficulty randomly associated to the footpath materials. For each scenario, participants had to answer two questions by dragging a cursor on a 100-point scale: (Q1) "On a scale from 0 (not at all) to 100 (extremely), how much are you bothered or annoyed by the sonic environment; (Q2) "On a scale from 0 (very bad) to 100 (very good) how would you assess the sonic environment?".

3. Results

The two questions' answer scores (Q1 and Q2) were associated to two independent variables: 'Annoyance' (AN) and 'Soundscape Quality' (SQ), respectively. A one-way repeated measures ANOVA was conducted on these variables with and without the cognitive task questions to evaluate the null hypothesis that there is no change in participants' scores with respect to the presented walked-on materials. The results of the ANOVA showed a significant material effect: Wilks' Lambda = .350, $F(3,186) = 115.240$, $p < .001$, $\eta^2 = 1.000$ for the Annoyance; Wilks' Lambda = .438, $F(3,186) = 79.641$, $p < .001$, $\eta^2 = 1.000$ for the for the Soundscape Quality. Therefore, there was significant statistical evidence to reject the null hypothesis for both the considered variables. Regarding the Annoyance, gravel (M = 58.91, SD = 24.55) differed significantly ($p < .001$) from grass (M = 26.34, SD = 21.47), wood (M = 32.68, SD = 20.95) and stone (M = 24.45, SD = 19.19). Similarly, regarding Soundscape Quality, the gravel (M = 32.00, SD = 21.99) resulted to be significantly different from all other materials ($p < .001$): grass (M = 58.95, SD = 20.84), wood (M = 52.98, SD = 21.38) and stone (M = 58.72, SD = 20.33). Figure 2 represents the individual scores' distributions of the four materials for Annoyance and Soundscape Quality, showing that the ranking of the materials was consistent for all the factors of the experimental design (i.e. country and background noise).

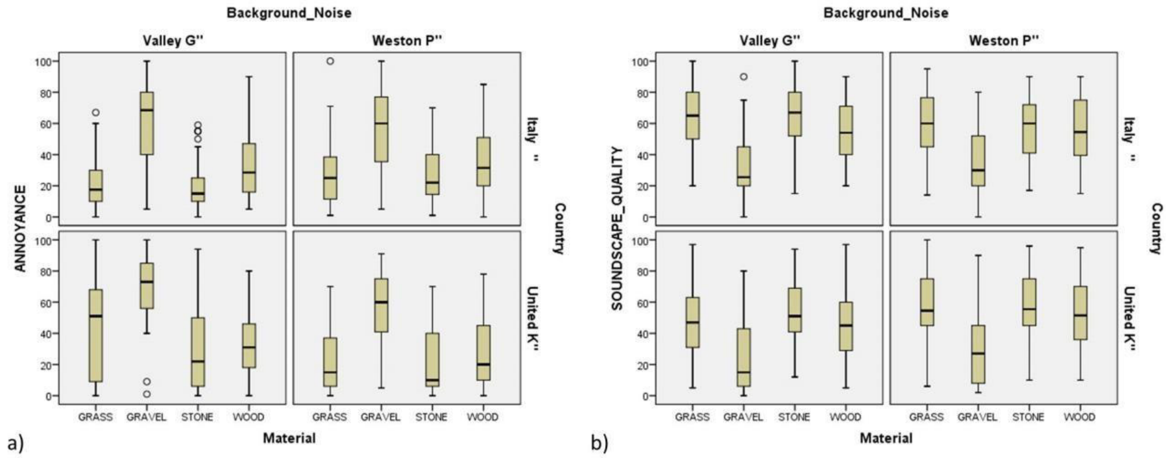

Fig. 2. Box-and-whisker plots showing individual scores distribution of the four materials for (a) Annoyance and (b) Soundscape Quality.

In order to investigate the effect of the background noise (context) and the cognitive task (activity) on the annoyance and soundscape quality variables, a set of paired samples t-tests were performed separately for the four footpath materials. Table 3 shows that there was a significant effect of the background noise on the Annoyance for the grass conditions and a significant effect on the Soundscape Quality for the wood condition. On the other hand, a significant effect of the cognitive task was observed on both Annoyance and Soundscape Quality for the wood, stone and gravel conditions.

Furthermore, an independent-samples t-test was conducted to compare Annoyance and Soundscape Quality scores between the sample groups (Torino and Sheffield). There was no significant difference in the scores of Annoyance for Torino (M=35.82, SD=24.28) and Sheffield (M=35.26, SD=27.58) groups; t (754) = 0.296, p = 0.768. Conversely, there was a significant difference in the scores of Soundscape Quality for Torino (M=52.42, SD=22.88) and Sheffield (M=48.00, SD=24.99) groups; t (754) = 2.503, p = 0.013. These results suggest that cultural and personal factors [10] are likely to affect how people assess the contribution of walking sounds to the soundscape quality of urban parks, while the samples tend to converge on the discomfort and burden appraisal.

Eventually, an independent-samples t-test was conducted to compare Soundscape Quality scores between the surveys performed under laboratory conditions and an online version circulated via web to a sample of 34 Italian and British persons. There was a significant difference in the scores of Soundscape Quality for the laboratory (M=47.85, SD=24.72) and web (M=55.18, SD=27.36) conditions; t (448) = 2.793, p = 0.005.

Table 3. t-tests for paired samples for the Annoyance and Soundscape Quality variables (Italian and English samples)

Variable	Tested factor	Material	t	df	Sig.
Annoyance	Background noise (Weston Park / Valley Gardens)	Grass	-2.206	62	**.031**
		Wood	-1.221	62	.227
		Stone	-.642	62	.523
		Gravel	-.888	62	.378
	Cognitive task (No Task / Task)	Grass	-1.677	62	.099
		Wood	-2.127	62	**.037**
		Stone	-2.639	62	**.011**
		Gravel	3.261	62	**.002**
Soundscape Quality	Background noise (Weston Park / Valley Gardens)	Grass	1.467	62	.147
		Wood	2.378	62	**.021**
		Stone	-.310	62	.758
		Gravel	1.392	62	.169
	Cognitive task (No Task / Task)	Grass	1.427	62	.159
		Wood	3.289	62	**.002**
		Stone	2.512	62	**.015**
		Gravel	-2.610	62	**.011**

4. Discussions and conclusions

This study aimed to investigate the effects of walking sounds from different footpath materials on the individual auditory perception of urban parks. The tested materials were grass, wood, stone and gravel: these were selected since they represent plausible design solutions for urban parks' footpaths. The environmental experience of urban parks is holistic and affected by several factors; consequently the ecological contribution of walking sounds might be limited in such contexts. Although, walking sounds are relevant sound sources in most of urban contexts, due to their high occurrence as non-verbal sounds [15] and for the sense of spatial presence they can provide. even if they are not the prevailing sound source of the sonic environment.

It was shown that different walked-on materials are likely to have an effect on soundscape perception: indeed, a statistically significant materials' effect was observed on both Annoyance and Soundscape Quality. In the investigated cases, gravel received the worst assessment: the mean differences between gravel and the other materials were: 31.1% for Annoyance and 24.9% for Soundscape Quality.

The soundscape approach acknowledges that the human experience of the acoustic environment overlies three main elements, namely the people, the context and the activity [16, 3]; therefore, the rationale for this research was to also to test the footpath materials' effect while manipulating such factors. Results from the t-tests suggest that different footpath materials in urban parks are likely to affect differently the acoustic environment, depending on other covariant factors like background noise, activity of the listener and cultural and personal factors. These results are consistent with other findings in literature showing that the acoustic comfort evaluation is affected by other but aural factors [17, 18].

There is still no clear consensus about the ecological validity of soundscape appreciation data collected under different conditions (e.g. on site, in laboratory, remotely). Recently, a crowd-sourced approach (e.g. web surveys, mobile applications) has been spreading in soundscape studies. Our preliminary analysis on the comparison between laboratory and web conditions, however, raises some questions about the reliability of the information collected under non-controlled conditions.

Further analysis is required to deeper investigate the effect of non-acoustical factor on the performance of the different walked-on materials, as data have been currently considered in an aggregated way. In general, this research shows that it is possible to implement new design approaches for walking sounds coming from different walked-on materials and claims for further investigation on the soundscape of urban parks.

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References

[1] European Parliament and Council. Directive 2002/49/EC relating to the assessment and management of environmental noise. Brussels: Publications Office of the European Union; 2002

[2] European Environment Agency. Good practice guide on quiet areas. Luxembourg: Publications Office of the European Union; 2014

[3] International Organization for Standardization. ISO 12913-1:2014 Acoustics Soundscape - Part 1: Definition and conceptual framework. Geneve: ISO; 2014

[4] Brambilla G, Maffei L. Responses to noise in urban parks and in rural quiet areas. Acta Acustica united with Acustica; 2006. 92(6), p. 881-886.

[5] Szeremeta B, Zannin PH. Analysis and evaluation of soundscapes in public parks through interviews and measurement of noise. Science of the Total Environment; 2009. 407, p. 6143-6149.

[6] Pheasant R, Watts G, Horoshenkov K. Validation of a Tranquillity Rating Prediction Tool. Acta Acustica united with Acustica; 2009. 95, p. 1024-1031

[7] Payne SR. The production of a Perceived Restorativeness Soundscape Scale. Applied Acoustics; 2013. 74, p. 255-263.

[8] Brambilla G, Gallo V, Zambon G. The Soundscape Quality in Some Urban Parks in Milan, Italy. International Journal of Environmental Research and Public Health; 2013. 10, p. 2348-2369.

[9] Brambilla G, Gallo V, Asdrubali F, D'Alessandro F. The perceived quality of soundscape in three urban parks in Rome. Journal of the Acoustical Society of America; 2013. 832-839.

[10] Liu J, Kang J, Luo T, Behm H. Landscape effects on soundscape experience in city parks. Science of the Total Environment; 2013. p. 454-455, p. 474-481

[11] Liu J, Kang J, Behm H, Luo T. Effects of landscape on soundscape perception: Soundwalks in city parks. Landscape and Urban Planning; 2014. 123, p. 30-40.

[12] Axelsson Ö, Nilsson ME, Hellström B, Lundén P. A field experiment on the impact of sounds from a jet-and-basin fountain on soundscape quality in an urban park. Landscape and Urban Planning; 2014. 123(1), p. 49-60

[13] Johansson A, Hammer P, Nilsson E.. Prediction of Subjective Response from Objective Measurements Applied to Walking Sound. Acta Acustica united with Acustica; 2004. 90, p. 161-170.

[14] Yu CJ, Kang J. Science of The Total Environment, Soundscape in the sustainable living environment: A cross-cultural comparison between the UK and Taiwan; 1 June 2014. p. 482-483 p. 501-509

[15] Ballas JA. Common factors in the identification of an assortment of brief everyday sounds. Journal of Experimental Psychology; 1993. 19, p. 250-267.

[16] Herranz Pascual k, Aspuru Soloaga I, Garcia Perez I. Proposed conceptual model of environmental experience as framework to study the soundscape. Proc. Internoise Conference, Lisbon; 2010

[17] Yang W, Kang J. Acoustic comfort evaluation in urban open public spaces, Applied Acoustics; 2005. 66, p. 211-229

[18] Yu L, Kang J. Factors influencing the sound preference in urban open spaces, Applied Acoustics; 2010, 71, p. 622-633.